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REPORT NUMBER 641

EFFECT OF A SUBMARINE PATROL ON VISUAL PROCESSES

by

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Bureau of Medicine and Surgery, Navy Department
Research Work Unit M4305.08-3001D.06



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ERRATA

For NSMRL Report No. 641:

Page 1, Col. 2 In the last sentence, omit the word 'first';
end the sentence with the word 'occluded.'

Page 2, Col. 1 Top line, delete

Page 4, Col. 1 Line 4, under Figure 4, Figure should be 0.37
diopters, instead of 0.28

EFFECT OF A SUBMARINE PATROL ON VISUAL PROCESSES

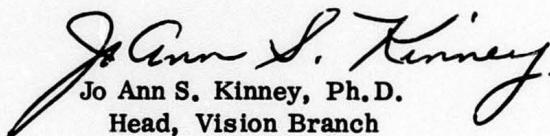
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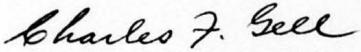
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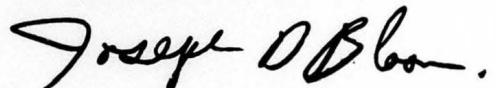
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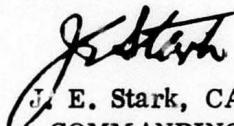
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SUMMARY PAGE

PROBLEM

To determine whether any measurable deterioration in basic visual processes occurs during one submarine patrol.

FINDINGS

Acuity, stereoacuity, and refractive power are not affected, but there is a significant increase in near esophoria, consistent with the long-term changes previously reported.

APPLICATION

These results are consistent with previous reports of visual deterioration aboard submarines and raise the question of the possibility and desirability of corrective action to preclude such changes.

ADMINISTRATIVE INFORMATION

The investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit M4305.08-3001D - Development of Visual Screening, Display, and Illumination Standards for Submarine/Shipboard Personnel. The present report is No. 6 on that Work Unit. It was approved for publication on 14 September 1970 and designated as Submarine Medical Research Laboratory Report No. 641.

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ABSTRACT

Two separate studies were undertaken to see if any measurable deterioration in basic visual processes occurred during one submarine patrol. There was no significant decline in acuity, stereoacuity, or refractive power, but there was a significant increase in near esophoria. This was consistent with long-term effects reported previously. The results are discussed and suggestions made for future research.

EFFECT OF A SUBMARINE PATROL ON VISUAL PROCESSES

INTRODUCTION

Two previous studies have shown that the visual efficiency of men who have served on submarines for many years is poorer than average,^{1,2} despite the fact that it was better than average at the start of their careers.³ The changes that have been observed are a loss of visual acuity, a tendency toward esophoria, and an indication of increased incidence of myopia.

While there are undoubtedly many possible explanations of these findings, the one that has most often been advanced centers on the confined environment of the submarine. It has been hypothesized that the small submarine compartments necessitate almost constant accommodation for near distances; this in turn is, of course, accompanied by binocular convergence.⁴ Extended confinement is presumed to result eventually in a loss of ability to relax accommodation. Consequently, there is an increase in myopia and loss of visual acuity, and the two eyes begin to assume some degree of convergence in the resting position; the latter is called esophoria.

Not all authorities agree that environmental factors can so produce refractive errors,^{5,6} but the submarine findings are consistent with numerous animal studies which have shown that monkeys placed in a confining visual environment suffer progressive visual impairment,⁷ notably an increase in myopia and a resulting loss of distance-vision. Since some animal studies

indicate that the vision of adult monkeys begins to show some deterioration as soon as the visual restrictions are imposed,⁸ the question arises as to whether or not there are any measurable changes in the visual processes of submariners during only one submarine patrol.

Two separate studies were carried out. In one, the Snellen acuity and subjective refraction of 100 officers and men were measured at the start and near the end of a 40-day patrol. In the second, checkerboard acuity, phoria, and depth perception were measured in 49 men at the start and throughout the course of a 10-week patrol.

APPARATUS AND PROCEDURE

Experiment I*

Visual acuity was measured with Snellen charts set at 20 feet from the subject and illuminated to about 21 foot-candles. To decrease the chance of learning, four different charts were frequently alternated. In addition, most charts had more than one line of the same size, and the subjects were also frequently asked to read the lines backwards.

Each eye was first tested individually with the other eye occluded, after

*Planned and carried out by Harris Newmark III, LT, MC,
USN, under Independent Research Project Number
MR011.01.5030.

which binocular acuity was measured. Records were kept not only of the smallest line correctly read, but also of the number of mistakes made on smaller lines.

Next, subjective refraction of each eye separately was carried out using lenses in eighth-diopter steps up to 1.25 diopters, quarter-diopter steps up to 3.5 diopters, and half-diopter steps up to 7.0 diopters. The measurement was always begun with a lens which was judged to be one plus diopter more than the subject needed; the lenses were then changed in a negative direction and the subject instructed to choose the lens which first gave him clear vision of the smallest line that could be read with any lens. The procedure was repeated if the subject went too far.

A total of 100 officers and men of the crew of a missile submarine were tested at the beginning of a 40-day patrol and retested starting 10 days before the end of the patrol. Since it took eight days to test everyone, the experimental period lasted in effect from 28 to 38 days, depending on when each man was available for testing.

Experiment II**

Using a Bausch and Lomb Modified Ortho-Rater, 49 men picked at random from the crew of a missile submarine were tested for visual acuity, both far and near; vertical and lateral phoria,

***Planned and carried out by Hugh Beatty, LT, MC, USN, under Independent Research Project Number MR011.01.5028.*

both far and near; and stereoacuity. The examinations were performed before the start of a 10-week patrol and approximately every ten days during its course. The procedure was that given in the Ortho-Rater instruction booklet.⁹

The intention was to test each man every ten days. Complete data are available for the preliminary and final tests and for the first two "experimental" sessions. On the third session, however, two men were not tested, and more than one-third of the subjects were not tested during the fourth and fifth sessions.

RESULTS

The distribution of Snellen acuities obtained in the preliminary examination of the first sample of 100 men is shown in Fig. 1. It is obvious that the visual acuity of this group is much better than average; 90% had at least 20/20 acuity, and more than half had better acuity than that. This is consistent with the previous findings³ that young submariners typically have good vision. (The mean age of this sample is not recorded, but it is presumably quite similar to that of the second experiment which was 23.4 with a range from 20 to 35.) The preferred corrections of those men with 20/20 acuity or better were skewed toward the minus (Fig. 2).

Figure 3 shows the distributions of changes in Snellen acuity after about a month on the submarine. More than 25% showed some degree of decrement, but at the same time nearly 50% showed some improvement and nearly 30% showed no change at all. The distribution

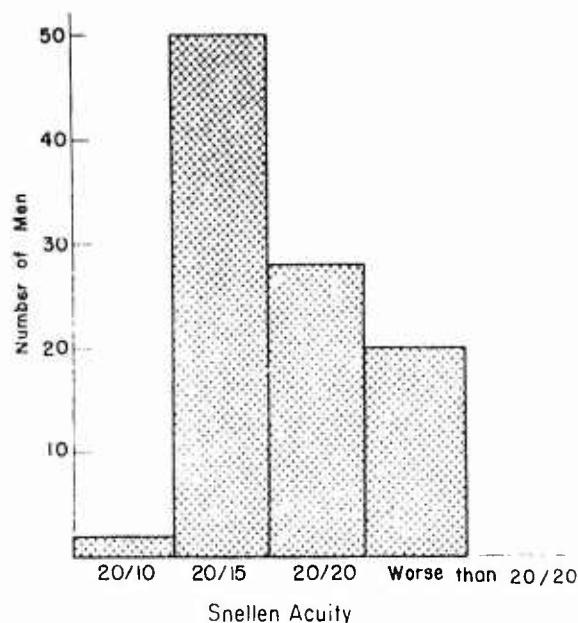


Fig. 1. Distribution of Snellen acuities obtained in preliminary examination.

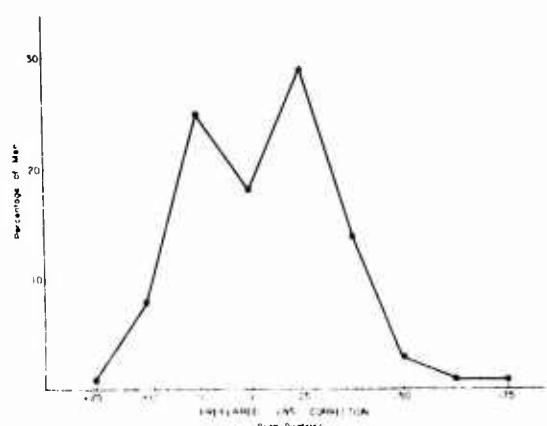


Fig. 2. Distribution of preferred lens correction found in preliminary examination (for men with 20/20 acuity or better).

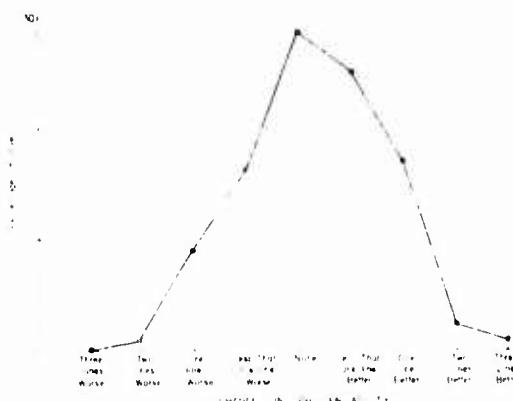


Fig. 3. Distribution of changes in Snellen acuity for individual eyes found after one month on the submarine relative to the preliminary examination.

of changes closely resembles a normal curve and suggests that most of them simply reflect error of measurement. The total percentage showing more than one line change in either direction is only 4.5%. The fact that most subjects showed improvement on the second test suggests a practice effect or possible some degree of learning. This is, of course, a common result in psychological testing. Some indication of the validity of the changes can be obtained by comparison with the results of the refraction measurements.

Figure 4 shows the refractive changes which were measured at the end of the month. Once again, we see a normal distribution with virtually the same number of positive and negative changes in the refractive power of the preferred lenses, when changes

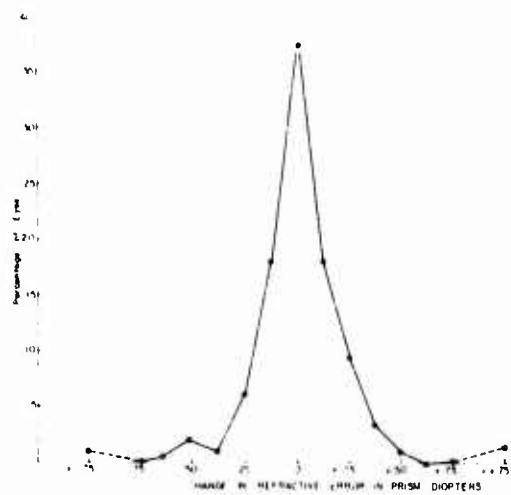


Fig. 4. Distribution of changes in refractive error for individual eyes found after one month on the submarine relative to the preliminary examination.

occurred; nearly 40% of the eyes tested required no change, however, and 94% of the eyes required a change no larger than 0.28 diopter. This is getting very close to the error of measurement for subjective refraction, particularly [redacted]

[redacted]. The results strongly suggest that no changes in refractive power of the eyes occurred.

The refractive changes of the 18 eyes whose Snellen acuity decreased were particularly noted. Twelve of the eyes required no change in refractive power, while the remaining six eyes all preferred a slight decrease in spectacle correction (averaging 0.21 diopters) again strongly suggesting no real changes in visual acuity.

The results of the second study are summarized in Table I. This presents the mean Ortho-Rater scores for the various visual functions tested on the 49 men who were examined both at the start and during the final week of the patrol. Scores are given only for the five test-sessions for which there is essentially complete data.

The first two sets of results in Table I are for vertical and lateral phoria at the near distance. It is clear that the mean scores for both functions were decreasing during the patrol. Mean vertical phoria declined from .08 right hyperphoria to .04, while mean lateral phoria declined from -4.32 to 3.40 diopters. The latter changes are plotted in Fig. 5 and a least squares regression line drawn through the set of points. An analysis of variance for single factor experiments with repeated measures on the same individuals shows that the changes in lateral phoria are statistically significant ($F=2.86$, $df=(4, 192)$, $p < .05$). It is also possible to test the assumption that the final mean score is significantly lower than any of the previous means. Such an analysis¹⁰ shows that the final mean score is significantly lowest in the series ($F=6.63$, $df=(1, 192)$, $p < .02$).

The changes in near vertical phoria are not significant, and the changes in phoria for the far distance are not regular and apparently do not decrease with time.

Acuity, both Snellen and checkerboard, progressively improved with repeated testing during the patrols.

Table I. Mean Ortho-Rater Scores for 49 Subjects by Test Session

Visual Function	Prelim.	1	2	3*	6 (Final)
NEAR					
Vertical Phoria (prism diopter)	.08 RH	.07	.07	.03	.04
Lateral Phoria	-4.32	-4.16	-4.50	-3.70	-3.40
Binocular acuity (min.vis. angle)	.877	.853	.848	.849	.845
Right Eye acuity	.884	.876	.874	.884	.876
Left Eye acuity	.919	.901	.890	.882	.892
FAR					
Vertical Phoria (prism diopter)	.26 RH	.26	.30	.29	.30
Lateral Phoria (prism diopter)	-0.9	-0.22	-0.13	-0.11	-0.13
Binocular acuity (min.vis. angle)	.956	.927	.910	.914	.870
Right Eye acuity	1.020	.982	.974	.956	.957
Left Eye acuity	1.045	.980	.996	.990	.993
Depth (stereo angle)	27.5	28.5	27.5	27.0	28.0

* N = 47

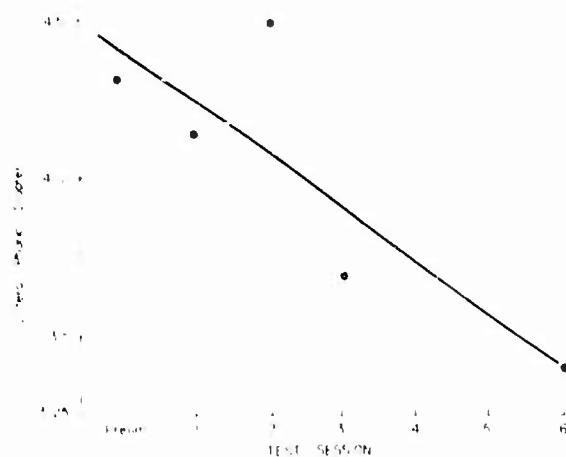


Fig. 5. Mean lateral phoria at each test session. Only incomplete data are available for the fourth and fifth sessions. The line is the least squares regression solution.

This is particularly true for binocular acuity, although monocular acuity may have levelled off by the fourth testing. The results are similar both for near and far distances. This is clearly evident in the second study with its repeated testing. The improvement is undoubtedly due to a practice effect or perhaps even to some learning of the test charts.

It is possible to determine whether both of these factors entered into the results or whether the improvement was merely a practice-effect, that is, an improved ability to use small cues to read the charts. If there were actual memorization of the charts rather than a simple practice effect, then we would expect the differences between monocular and binocular scores to decrease. A genuine practice effect, however, ought to permit binocular acuity to maintain its superiority. Table I shows that mean binocular

acuity is always better than monocular acuity with either eye, while acuity with the right eye is almost always better than that with the left eye. The ratio of monocular to binocular acuity for each eye is given in Table II for the five test sessions. There is no improvement in relative monocular acuity with repeated testing, suggesting that the improvement over time is a simple practice effect and does not involve memorization of the test charts.

Table II. Ratio of Monocular to Binocular Acuity for Each Eye During the Various Test-Sessions

	Prelim.	1	2	3	6
FAR R	.934	.943	.935	.951	.941
	.913	.936	.913	.922	.911
NEAR R	.993	.969	.972	.962	.967
	.955	.944	.955	.957	.950

Left unanswered, however, is the question of whether the practice effect has obscured some deterioration in acuity during the patrol which might have been apparent if the subjects had been highly practiced to begin with. In any event, it seems certain that any deterioration would have been small.

Finally, there was no significant change in depth perception during the patrol.

DISCUSSION

These two studies were undertaken to see if, during one submarine patrol,

there were any measurable decrements in acuity, stereoacuity, refractive error, or phoria. Of these processes, phoria has been shown to be very sensitive to the effects of environmental manipulations, while acuity is relatively insensitive.¹¹ Indeed, although there was no significant decrement in acuity, stereoacuity or refractive error, there were systematic and statistically significant changes in near lateral phorias. These amounted to nearly one prism diopter in the direction of esophoria and away from the appreciable degree of esophoria which large scale studies have shown to be the norm for near vision in a young population (see ref. 2). This is consistent with the long-term changes previously reported. Schwartz and Sandberg¹ found that in a sample of 1,064 submariners, with an average of about four years in the submarine fleet, there had been a shift of 0.8 diopters in the direction of esophoria compared to a sample of candidates for submarine school. When Weitzman, Kinney, and Ryan tested 51 available men from the original group 15 years later, they found an additional shift of 1.4 diopters in an esophoria direction.²

Viewed in this context, the change of 0.9 diopters during the course of one patrol is sizable--indeed, surprising. Had this study been carried out first, much larger changes in phoria would have been predicted over a period of years than have actually been found. This suggests, then, that there may well be reversals of this shift in phoria when the men return to shore. Permanent changes in phoria may then occur either as the result of (1) some cumulative change with addi-

tional time in submarines, or (2) increasing magnitude of shifts during a patrol with increasing age, or (3) a decreasing ability of an aging visual system to effect the reversal after returning to shore.

To decide among these alternatives and to obtain additional information as to the cause of the changes, it would be of interest, first of all, to test individuals showing a change in phoria during a patrol for a certain time after the patrol to see if there is a reversal in the phoria-shift, its magnitude, and how long it takes. Second, are there differences in susceptibility to these changes among men of different age groups?

A third question is prompted by the common assumption that the visual changes result from the lack of opportunity to relax accommodation in the confined quarters of a submarine. Are there, then, differences in susceptibility to these changes as a function of a man's duties or the amount of close work which he typically does? Will periscope operators, for example, show fewer changes while men who read a great deal show more changes? If so, is it possible to reduce the amount of visual change by providing opportunities for relaxation of accommodation?

The answers to these questions are uncertain, because the mechanism of accommodation is unexpectedly complex and many details are not yet clear.¹² The usual description is that the lens, in its capsule, is suspended from the ciliary body on all sides by the zonule of Zinn. When the eye is at

rest, the zonule is (surprisingly) taut and exerts a pull on the lens-capsule which keeps it flat; during accommodation, the ciliary muscle contracts, pulling the choroid forward and releasing the tension on the zonule, thus allowing the lens capsule to contract by its inherent elasticity and become more convex.¹³ It is assumed, therefore, that contraction of the ciliary muscle for long periods of time results in a spasm of the muscle and a consequent inability to relax.

One argument against the spasm-theory is that modern submarines do provide opportunities for distance (i.e., 20 feet) accommodation. Nevertheless, it seems reasonable to assume that there will be far fewer instances of accommodation for 20 feet on a submarine than typically occurs in a more usual environment. A more cogent argument rests on Duke-Elder's observation that "True spasm of the ciliary muscle...is rare...a high degree of myopia being produced."¹⁴

Another argument is that it seems reasonable to assume that the ciliary muscle is relaxed during sleep and is thus provided with the necessary relaxation. This, however, does not seem to be the case. It is well known that in the absence of any stimulus to accommodation, the eye is appreciably near-sighted.¹⁵ This is true whether the absence of stimulation results from the absence of a target or the absence of light itself. The resulting visual conditions are known as empty-field myopia and night-myopia respectively. It seems certain, therefore, that the eye is myopic during sleep also. Indeed, it has been argued that this

would be a protective mechanism designed to insure that if one is awakened by the presence of a predator, the eye will be focused at a near distance since there is danger only from predators which are nearby.

In addition, Tschermak-Seysenegg has pointed out that the "tonus-free absolute position of rest... normally does not occur during life but only in total ophthalmoplegia and immediately after death, before rigor mortis sets in" (his italics)¹⁶.

On balance, it appears that while true spasm may be rare, excessive accommodation with inadequate periods of relaxation is the rule on submarines, and such conditions may well lead to the esophoria which apparently develops rapidly and to the myopia which develops subsequently.

A following study which would have significance is an investigation of the extent to which such changes as the shift toward esophoria reported here can be arrested by providing frequent periods of distance-viewing, either optically or in a long passageway. The SMRL considers this of importance and proposes to continue this investigation at sea for the purpose of determining whether or not this visual esophoric aberration can be eliminated.

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